National Institute of Biomedical Imaging and Bioengineering

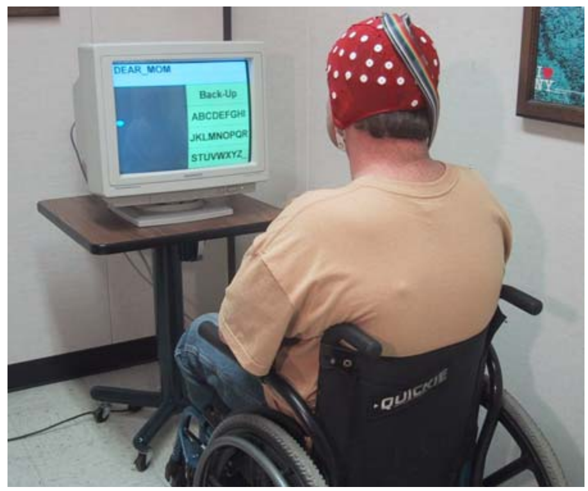
Catch a (Brain) Wave

About 2 million people in the United States have diseases, such as cerebral palsy or amyotrophic lateral sclerosis that impair their ability to control their muscles. Those most severely affected may lose all muscle control, including eye movements and breathing. Although life-support systems can keep these people alive, they are often “locked into” their bodies, unable to grasp objects, work appliances, blink their eyes, or communicate in any way.

To help these patients communicate and control their environment, scientists are developing computer programs that capture a patient’s electrical brain waves and translate them into commands that drive applications such as word-processing programs, an electric wheelchair, or a robotic arm. With these programs, patients once immobile and helpless may eventually be able to communicate and gain a small measure of independence – all through the power of their brain signals.

Creating a Framework

Known as brain-computer interfaces (BCIs), these systems rely on the direct interaction of a patient’s brain with a personal computer to interpret the brain signals and drive applications. Several research groups are working on BCI systems. One of the major challenges they face is compatibility across systems. To standardize BCIs and allow researchers to readily compare different systems, Dr. Jonathan Wolpaw, a research neurologist at the Wadsworth Center in Albany, NewYork, worked with his colleagues to design a computer program called BCI2000.



By controlling the vertical movements of the cursor that is moving from left to right, this patient is able to select letters from groups of letters on the right side of the screen.
Photo courtesy of Dr. Jonathan Wolpaw.

“BCI2000 was configured so that you can use different brain signals, different signal-processing methods, and different applications, all within the same basic framework,” says Dr. Wolpaw. The flexible platform eliminates the need to create a whole new system in each experiment. This reduces the time, effort, and expense of testing and using new BCI designs. BCI2000 uses relatively inexpensive hardware components and can be mastered by researchers lacking specialized expertise in software design.

In Dr. Wolpaw’s BCI system, the patient is first fitted with a cap of electrodes that record brain signals from the scalp. The cap is attached by wires to a personal computer. The computer program is able to analyze the patient’s EEG (electroencephalogram) – a recording of the voltage on the skull generated by electrical currents emanating from nerve cells in the brain.

Controlling Brain Waves

To select a brain wave with which to begin training, investigators tell a patient to imagine an activity. “We suggest that they think about moving a hand or foot, but patients are free to try different types of imagery and see what works for them,” says Dr. Wolpaw. “One person thought about shooting baskets; another thought about lifting weights.” The computer then selects the brain wave that the patient is best able to control and links the brain wave to the movement of a cursor on a computer screen. The patient gradually learns to control the amplitude of that particular brain wave to control the movement of the cursor.

Learning to vary the amplitude is a somewhat mysterious process that requires several weeks of practice to master well. “It’s basically a trial-and-error process, much like the way you learn any other skill,” says Dr. Wolpaw. “When you first start playing tennis, you try different ways of holding the racket. If something works, you do it again. If it doesn't, you don't." Eventually, patients become so skilled in moving the cursor that they do not need to rely as much on their imagery. "It becomes natural, like moving an arm," he says. In one-dimensional control, patients vary the brain wave amplitude to move the cursor up or down on a computer monitor. Learning to move the cursor in one dimension enables patients to answer yes or no questions – they move the cursor to the top of the screen to answer "yes" or move it to the bottom to answer "no." Learning to vary the amplitude more precisely allows patients to operate simple word-processing programs. This can be accomplished with one-dimensional control, with the patient controlling the vertical movement of a cursor as the cursor travels across the screen at a steady rate. This simple application allows the user to write about one word per minute.

"You and I would consider that slow, but if that's your only means of communication, it's not so slow," says Dr. Wolpaw. Using BCI2000, Dr. Wolpaw's group has extended the range of EEG-based BCI to control a cursor in two dimensions. Use of multiple dimensions may eventually allow patients to control a robotic arm or an electric wheelchair.

An Alternative System

Working with Dr. Wolpaw and another member of his laboratory, Dr. Gerwin Schalk, researchers from Washington University in St. Louis used BCI2000 to extract brain signals using another type of recording called electrocorticography (ECoG), which records electrical activity with grids of electrodes surgically implanted inside the head on the brain's surface. ECoG signals are clearer and comprise a broader range of frequencies than EEG signals because ECoG signals do not have to travel out through the skull before reaching a recording electrode. With this system, patients learned to manipulate a cursor in less than half an hour, rather than the multiple sessions needed when using EEG. Although the signals produced by ECoG are superior to EEG signals, Dr. Wolpaw and other researchers have not lost interest in EEG-based systems, in part because EEG does not require that electrodes be surgically implanted inside the head.

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References

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